Constraints on Spacetime non-commutativity from CMB and LSS

Joby Kochappan

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Collaborators: Pravabati Chingangbam, Benjamin L'Huillier, Cristiano Sabiu

Non-commutative Spacetime model

* Quantum theories of gravity suggest that spacetime is non-commutative at length scales close to the Planck length.

$$\left[\hat{x}_\mu, \hat{x}_\nu\right] = i\theta_{\mu,\nu}$$

* Introduces a special spatial direction: $\vec{\theta}^0 = \theta\hat{\theta}^0$

Modified Power Spectrum

* Modified primordial scalar power spectrum:

$$P_\theta(\vec{k}) = P_0(k)\left[1 + \frac{H^2}{2}\left(\vec{\theta}^0 \cdot \vec{k}\right)^2\right]$$

* Modified CMB power spectrum:

$$\mathscr{C}_\ell^{TT} = \int \mathrm{d}k k^2 P_0(k) \left|\Delta_\ell^T(k)\right|^2 \frac{\sinh(\theta H k)}{\theta H k} \qquad \mathscr{C}_\ell^{EE} = \int \mathrm{d}k k^2 P_0(k) \left|\Delta_\ell^E(k)\right|^2 \frac{\sinh(\theta H k)}{\theta H k}$$

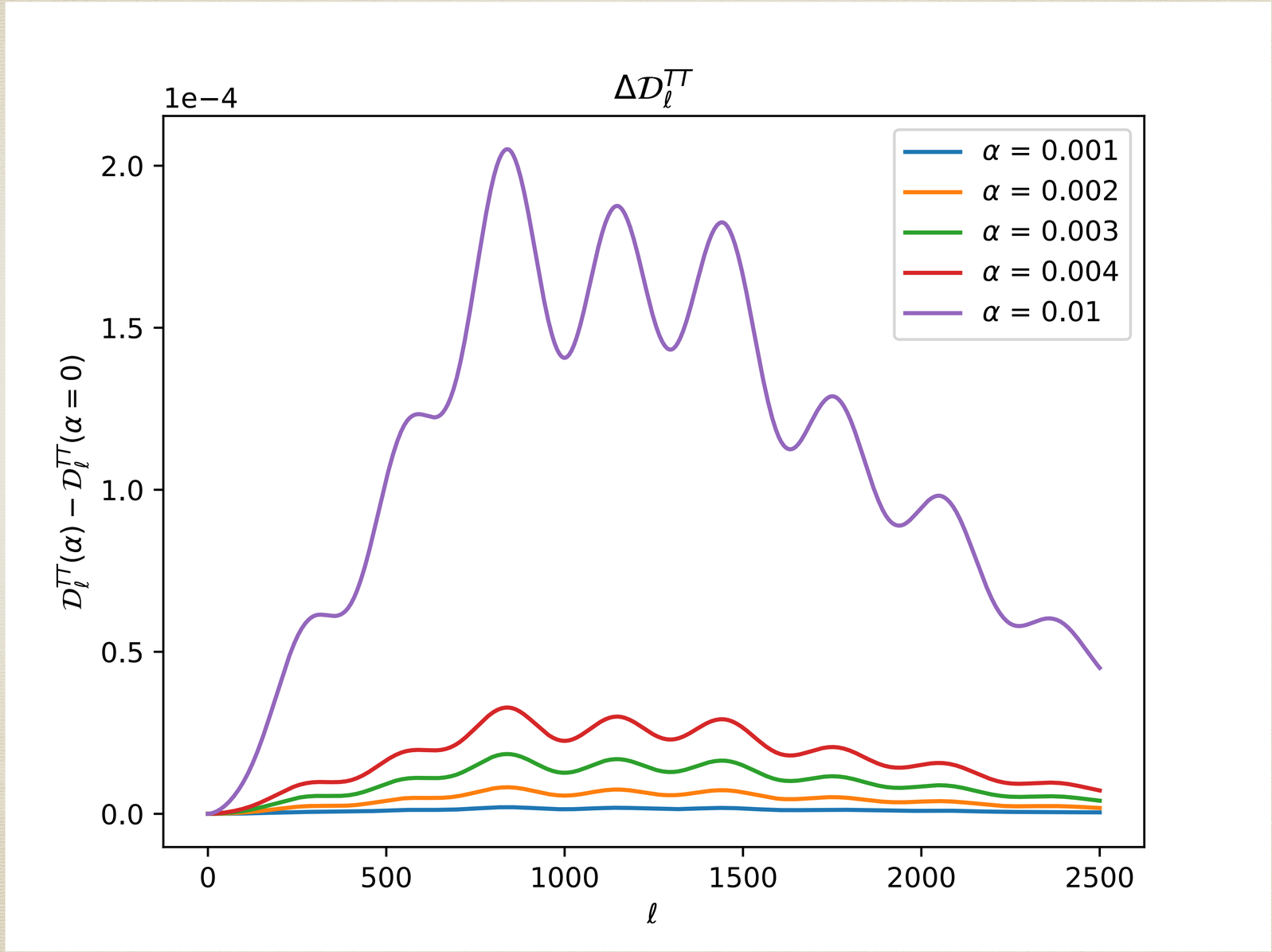
Method

* Modify the primordial scalar power spectrum in CAMB to accommodate the additional $\frac{\sinh(\theta H k)}{\theta H k}$ factor.
* Compute modified CMB power spectra for noncommutative spacetime.
* Run MCMC with modified CAMB to get constraints on $\alpha = \theta H$.
* Use H during inflation to constrain θ.

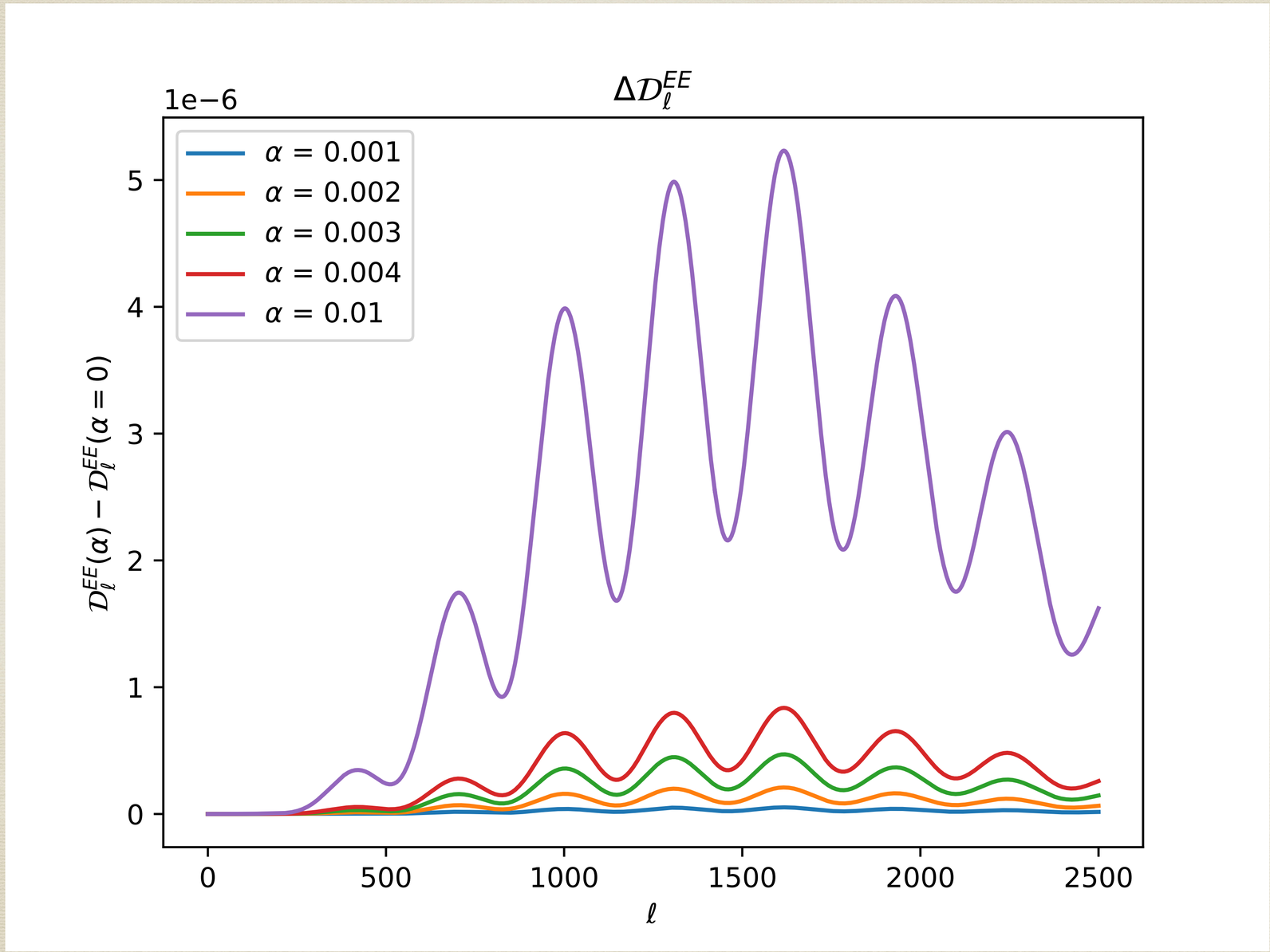
Previous Constraints

* Akofor et al. (2009), with WMAP, ACBAR and CBI data got $\sqrt{\theta} < 1.36 \times 10^{-19}$m.
* Joby et al. (2015), with Planck 2013, got $\sqrt{\theta} < 0.653 \times 10^{-19}$m.
* Improvement by a factor of ≈ 2, comes from higher angular resolution and precision of Planck data.

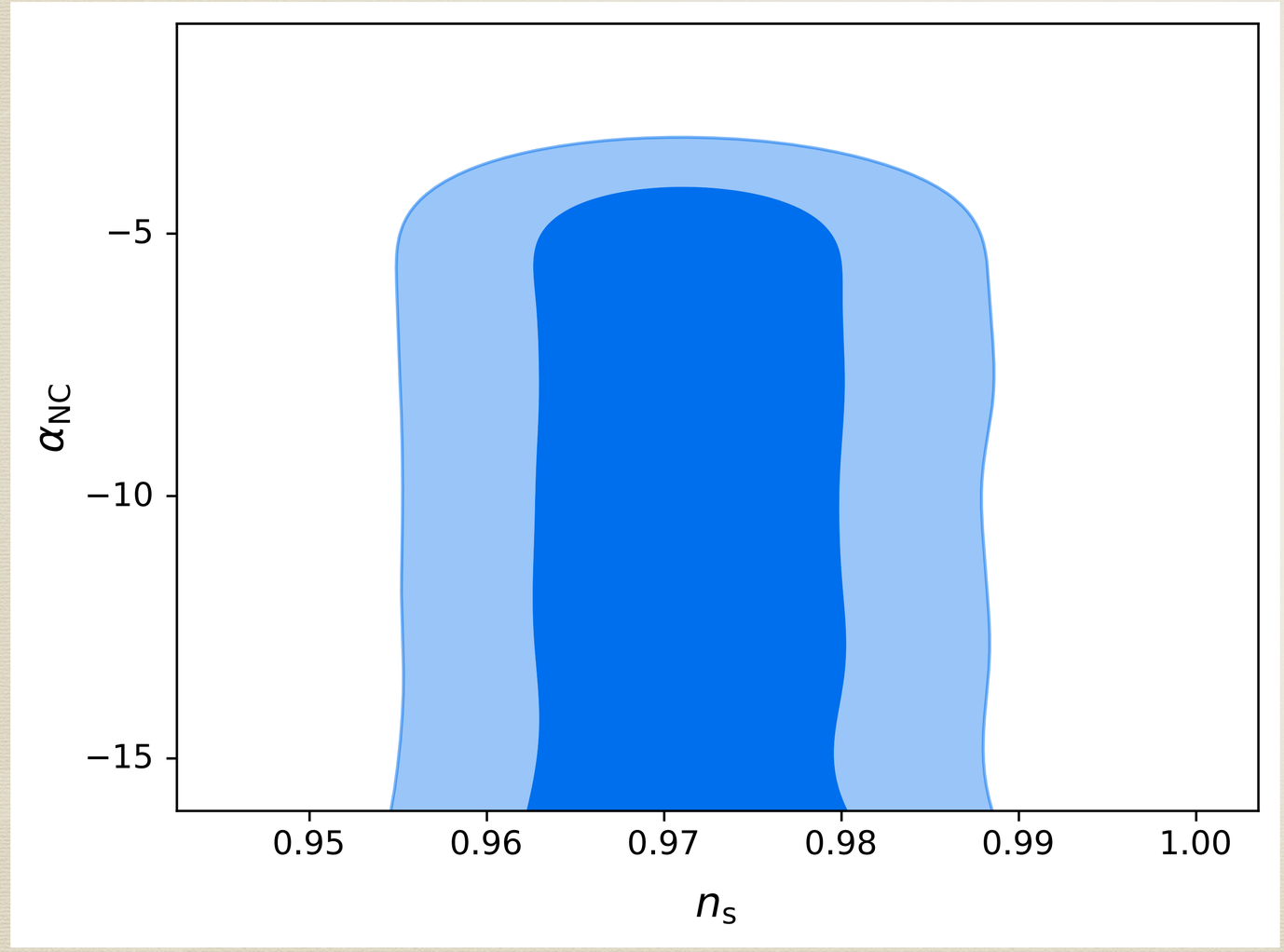
Modified CMB (TT) power spectrum



Modified CMB (EE) power spectrum



Constraint from Planck 2018 data



* Marginalised upper bound: $\log_e(\alpha) < -7.66$
* $\alpha < 0.00047$
* Length scale $\sqrt{(\theta)} < 0.277 \times 10^{-19}\mathrm{m}$

How far can we get with CMB data?

* Fisher matrix estimate for future CMB experiments.
* For $\ell_{max} > 3000$, with error bars comparable to cosmic variance, what is the expected constraint on θ?
* At which ℓ_{max} do the constraints saturate?

Constraint from LSS simulations

* Linear matter power spectrum from modified CAMB for noncommutative spacetime.
* N-body simulations to estimate late time matter power spectrum.
* Constrain θ by comparing with simulations of commutative spacetime.
* How does this constraint compare to the constraint from CMB data?

Summary

* We have considered the prediction of noncommutative spacetime for the CMB and matter power spectra.
* The modification introduces a factor that increases exponentially at smaller scales.
* Constraint from Planck 2018 data: $\sqrt{(\theta)} < 0.277 \times 10^{-19}\mathrm{m}$
* Forecast constraint from future CMB experiments.
* Constraint from simulations of matter density distribution.